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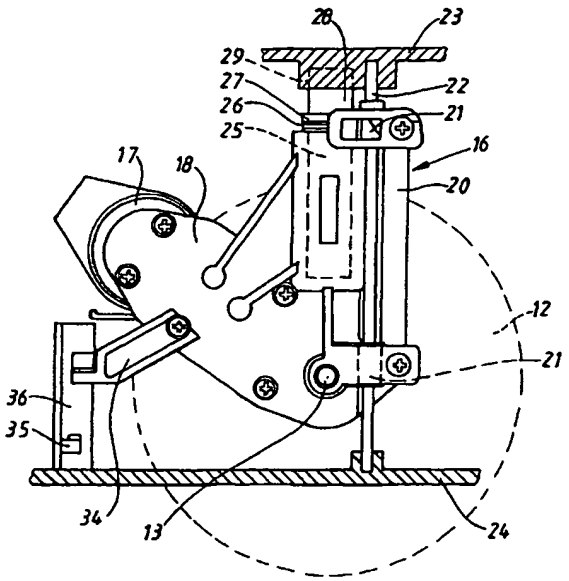
(54) Title: WHEEL SUPPORT ARRANGEMENT FOR AN AUTONOMOUS CLEANING APPARATUS



(57) Abstract: An autonomous cleaning apparatus such as a robot vacuum cleaner. The apparatus has a housing enclosing a dust container and an electrically driven vacuum source and also has a nozzle through which dust particles flow into the dust container. The housing is directly or indirectly supported by a wheel arrangement having at least two individually driven wheels (12). Each drive wheel is supported by a removable drive wheel support (16) which is arranged to be pressed towards a floor surface by means

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Wheel Support Arrangement for an Autonomous Cleaning Apparatus

This invention relates in general to wheel structures, and more particularly to a wheel support arrangement for an autonomous cleaning apparatus, such as a vacuum cleaner robot. Such a robot vacuum cleaner typically comprise a housing enclosing a dust or dirt container, and an electrically driven vacuum source dor drawing dust and dirt into the container. A floor engaging nozzle, through which dust and dirt flow into the dust container, is also contained within the housing. The housing is directly or indirectly supported by a wheel arrangement having at least two individually driven wheels for moving the vacuum cleaner about a floor surface.

Robot vacuum cleaners of the type described above are known, see for instance WO 9740734 and EP-A-803224. These robot vacuum cleaners, which preferably are battery driven, are provided with a circular housing and with means for sensing the surrounding objects so as to avoid, or otherwise deal with, such objects during a vacuum cleaning operation. Depending on existing objects or other obstacles, the vacuum cleaner is automatically guided around the objects or obstacles and can vacuum hard as well as soft floor surfaces. The driving wheels are typically arranged for rotation on two horizontal shafts that are placed in coaxial alignment with one another for rotation on a common axis, and are rotatably supported by bearings permanently fixed in posistion relative to the housing. Because of the circular housing shape, and by driving the wheels with different velocities and in different rotational directions, the vacuum cleaner can be automatically guided such that tendecies to get stuck or otherwise restrained in its operation are minimized.

Even if the prior art arrangement descibed above works well most of the time, operational failure, with this type of fixed wheel arrangement, can occur wherein the movement of the vacuum cleaner be encountered, for example, by rugs having high edges, thresholds, loose edges or other obstacles.

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Even if the prior art arrangement descibed above works well most of the time, operational failure, with this type of fixed wheel arrangement, can occur wherein the movement of the vacuum cleaner be encountered, for example, by rugs having high edges, thresholds, loose edges or other obstacles.

In order to minimize the above-noted problems, drive wheel arrangements having individual wheel supports, e.g. taught by U.S. Patent 5,815,880, have been suggested to allow the wheels to engage the floor surface even if there are some recesses, some indulations, or the like in the floor surface.

The purpose of the persent invention is to achieve a simple and efficient, self-adjusting wheel supporting arrangement for a cleaning apparatus, preferably a robot vacuum cleaner, wherein the vacuum cleaner easily climbs over or otherwise avoids objects and obstacles it may encounter during its operation.

An embodiment of the invention will now be described with reference to the accompanying drawings wherein:

FIG. 1 in a perspective view shows a vacuum cleaner for which the invention is intended to be used;

FIG. 2 shows schematically a partly broken side view of the vacuum cleaner shown in Fig. 1;

FIG. 3 shows a further partly broken side view of the vacuum cleaner of Fig. 1;

FIG. 4 shows the drive wheel arrangement of the vacuum cleaner in a position in which the vacuum cleaner rests on a floor surface;

FIG. 5 shows a perspective view of the drive wheel structure before it is assembled with a driving wheel and before it is mounted into the vacuum cleaner housing; and

FIG. 6 is a plan view of the drive wheel arrangement shown in Fig. 5 with a drive wheel mounted.

With reference to Figs. 1-3, the autonomous cleaning apparatus, or robot vacuum cleaner in accordance with the present invention, has a circular housing 10 with a cover 11 concealing a chamber in which a dust container or collector, designed as a filter cassette or a filter container F, is inserted. Alternatively, the housing might enclose a centrifuge cyclone separator well known in the art, by

means of which dust and particles are separated from the air and are collected in the dust container F. The housing 10 also encloses a vacuum source V, typically a motor driven fan unit that is driven by an electric source such as a battery B located in a battery holder. The container F is connected in fluid communication to a nozzle M arranged at the bottom of the housing and through which the dust and dirt laden air is sucked into or evacuated into the container F, in a conventional manner. The nozzle M encloses and rotatably supports a rotating brush roll S that loosens dust and dirt from the surface so that it can be more readily vacuumed. The housing also encloses the usual electric circuits and control means that are necessary for driving the fan unit and the brush roll, as well as means for automatically guiding the robot vacuum cleaner about the floor surface of the room, for example by means of ultrasonic transmitters and receivers with associated microprocessor-based controls and related sensors intended to map and alter the appropriate pattern of movement of the vacuum cleaner when hitting an object or obstacle.

The robot vacuum cleaner is also provided, see Fig. 2, with two diametrically opposite drive wheels 12 that are placed close to the periphery of the housing. Each drive wheel is rotatably attached to a drive wheel shaft 13 and there also are two support means 14 and 15. The support means can be implemented by using rear rolls 14 and a front roll 15, or by using wheels, for example. The rear rolls 14 and front roll 15 are rotatably attached to the housing 10 and the rolls 14 and 15 aid in supporting the robot vacuum cleaner, rotating to aid the movement of the robot vacuum cleaner across the floor surface. The rear rolls 14 are placed at each side of a central axis directed in the movement direction of the vacuum cleaner (i.e. to the right in Fig. 2) and behind the drive wheel shafts whereas the front roll 15 is placed centrally in front of the drive shafts 13. The support means 14 and 15 provide a gap between the bottom of the robot vacuum cleaner and the floor surface when the floor is somewhat hard and substantially flat and/or substantially smooth.

The drive wheels 12 preferably have toothed plastic or rubber treads or are made of some other material having a high friction coefficient in order to avoid slippage when in contact with the floor surface. Each drive wheel shaft 13 is supported on a drive wheel support 16, as shown in Fig. 4. The drive wheel supports each support an electric motor 17 and a transmission 18, such as a cog

wheel transmission or the like. Each transmission 18 connects a motor shaft of the electric motor with the corresponding drive wheel shaft 13. The transmissions 18 gear down the revolution of the electric motor to the drive wheel 12, thereby increasing torque. Thus, each of the two drive wheel supports integrates the corresponding motor, transmission and drive wheel into a single integrated unit that can be easily mounted into the housing providing a pair of integrated units.

The vacuum cleaner is also provided with further support means 19 arranged at the front, bottom part of the vacuum cleaner. The further support means 19 can be implemented by rolls or wheels, for example. During normal forward motion of the vacuum cleaner on a hard, substantially flat floor surface, the further support means 19 are typically positioned somewhat above the floor surface providing a some distances, or gap, between the further support means and the floos surface, and thus do not contact the floor surface. However, when the robot vacuum cleaner encounters a loose or flabby rug, or another relatively shallow obstacle, the further support means 19 come into contact with the rug or obstacle, enabling the vacuum cleaner to climb up and over such rugs and/or obstacles, whithout wrinkling or scrunching them and without being overly hindered. The bottom front of the housing is also provided with a forwardly, upwardly slanting portion 19a to facilitate the ability of the robot vacuum cleaner to climb over objects, obstructions, and uneven surfaces.

The drive wheel support 16, is arranged to allow drive wheel support 16 movement in a vertical direction within the housing, shown in a first embodiment provided with a first upwardly directed part 20 with a fastening means for an upper and a lower slide bearing 21 surrounding a vertical slide rail 22 fixed at the upper and lower wall part 23 and 24 of the housing. The slide rail 22 serves as a means for guiding the vertical movement of the wheel support arrangement, allowing the wheel to remain in contact with teh floor surface should the surface be uneven or bumpy or should the robot vacuum cleanr encounter obstructions or objects. Other guide means may also be employed to guide the vertical movement of the wheel support arrangement.

The upwardly directed part 20 of the drive wheel support has means for receiving a dowel 25. For example, a cylindrical device with an upwardly open

recess can be used to enclose a dowel 25. The dowel 25 is connected to a force creating means, such as a coil spring 26, or some other compressible resilient device, for example. The dowel is positioned such that it normally can be moved vertically up and down under the influence of the force creating means or spring. The spring 26 is designed such that the force created by the spring on the drive wheel support is approximately constant during the movement of the drive wheel support. The dowel 25 has an annular, extending, collar 27 which one end of the spring abuts whereas the other end of the spring rests against the bottom of the recess. The upper end 28 of the dowel rests in a seat 29 in the upper wall part 23 of the housing. The collar 27 has a vertically directed tongue 30 (see Fig. 5) that extends parallel to the upwardly directed part 20 and the tongue has a hook shaped portion 31 which is mounted in the housing before the drive wheel support 16. The hook shaped portion 31 cooperates with a stop means 32, such as a tab, arranged at the outside of the upwardly directed part 20.

The tongue 30 is at its lower part provided with a lug, not shown, cooperating with an additional stop means 33 arranged on the upwardly directed part 20. The lug and the stop means 33 cooperate in such a manner that the movement of the dowel is limited to avoid becomming free from the upwardly directed part 20. Thereby the risk is reduced that the components become separated from one another under the influence of the spring forces when the drive wheel arrangement is mounted or demounted from the chassis.

Each drive wheel support 16 also has an extending arm 34 whose outer end is intended to cooperate with a micro switch 35 arranged at a bracket 36 at the lower wall part 24 of the housing. The micro switch 35 is acted on when the wheel 12 is in its extended position, for ecample, when the vacuum cleaner is lifted from the surface or when the wheel has taken a position which indicates that the vacuum cleaner has gotten stuck at any of a variety of potential obstacles. The two micro switches 35 are thus connected to the electric circuit of the robot vacuum cleaner such that the function of the robot vacuum cleaner is suitably influenced if one or the two wheels are moved to their extended positions (for example, the vacuum cleaner motor may be deactivated, or the direction of rotation of one or both wheels may be changed, among others).

The robot vacuum cleaner and the wheel support are assembled, in one embodiment, in the following manner: The wheel support 16 is prepared for mounting by placing the spring 26 together with the dowel 25, and inserting them into the recess in the vertical part 20. The dowel 25 is then depressed and turned so that the hook 31 of the tongue 30 engages the stop means 32 such that the dowel is locked with the spring 26 tensioned in a compressed , lower position. Before or simultaneously, the drive wheel 12 is fixed on the shaft 13. Tthe complete wheel support 16 is then placed on the lower wall part 24 of the housing by means of the slide rail 22, after which the housing with the seat 29 is placed at the upper part of the dowel 25 at the same time as the upper part of the slide rail 22 is inserted in a corresponding recess in the upper wall part 23. Then the upper wall part 23 is connected to the lower wall part 24 after which the hook 31 is released from the stop means 32 by turning the dowel 25. This turning motion is achieved by means of an extending lug, not shown, in the seat 29 cooperating with the upper part of the dowel 25 and which, after being turned, prevents the dowel from being unintentionally turned and thereby prevents the dowel from getting stuck in a locked position. Consequently, the weight of the vacuum cleaner, when it is placed on a surface, will rest on the springs of the two wheel supports and press them together.

When the robot vacuum cleaner is placed on a floor and is activated it will move forwards on the floor surface (i.e. to the right in Fig 2) and continue according to a movement path defined by a microprocessor. At the same time, the floor surface is brushed by the brush roll S and dust laden air and/or dirt is sucked in through the nozzle M by means of the fan unit V. The dust laden air and/or dirt flows into the filter container F where particles, dirt, and other solids are separated from the air, while the air continues to flow through the fan to several outlet openings arranged in the housing, where the air exits the robot vacuum cleaner.

When the vacuum cleaner is placed on the floor surface, its weight causes the drive wheel support 16 and hence the drive wheels to move from a resilient extended to a partially retracted position. This means that the weight of the vacuum cleaner will overcome some portion of the force that the springs 26 create on the drive wheel supports 16. The vertical movement of the drive wheel support is limited by the engagement of a suport means 14, 15, with the surface. Support means 14, 15

can be implemented by using rolls or wheels, for example. When the drive wheel supports 16 are depressed, control knobs 34 are released, signalling the electric circuit of the robot vacuum cleaner and notifying the microprocessor, which reacts such that the vacuum cleaner is activated, and begins to move on the floor.

If the peripheral, slanted portion at the front part of the bottom of the housing engages an obstacle or object on the floor surface having a height change or uneven surface (for instance a treshold or the end of a rug) during the movement of the robot vacuum cleaner, then the vacuum cleaner will tilt upwards about the rear support roll 14 such that the part that engages the obstacle will rise, and thus the complete drive wheel support with the drive wheels 21 will spring downwards such that the drive wheels are kept in contact with the floor surface, whereby the drive wheels are capable of driving the vacuum cleaner further over the obstacle or uneven surface. The tilting motion described above, which depends on the influence of the torque of the drive wheels and the position of the center of gravity with respect to drive wheels and support wheels, also occurs when the movement of the vacuum cleaner is hindered by other reasons. This also contributes to increase the passability of the vacuum cleaner on soft rugs where the wheels have a tendency to sink down heavily into the rug.

When the vacuum cleaner moves on a hard floor the support rolls 14, 15 will be in touch with the floor, such that the nozzle M is placed slightly above the surface whereby dust laden air and dirt flows into the slot between the surface and the nozzle. When the vacuum cleaner moves on a soft floor, for example a rug, the support rolls and drive wheels will sink down somewhat into the rug whereby the nozle opening touches, or very nearly touches, the surface.

Claims

1. An autonomous cleaning apparatus comprising : a housing (10) enclosing a dust container (V) and an electrically driven vacuum source (V); the housing having a nozzle (M) through which air and dust particles flow into the dust container; a wheel arrangement supporting the housing, the wheel arrangement having at least two individually driven drive wheels (12), **characterized in** that each drive wheel (12) is rotatably fastened to a corresponding drive wheel support, and wherein the drive wheel support (16) with the corresponding drive wheel can rise and sink in a substantially vertical motion with respect to the housing, and further wherein the drive wheel support (16) is arranged such that the corresponding drive wheel is directed towards a floor surface by a force creating means; the drive wheel support (16) including an electric motor (17) connected to a transmission (18) for driving the drive wheel (12); the drive wheel support also including means (21) for cooperating with a guide (22) in order to achieve a linear, substantially vertical motion of the drive wheel support (16).

2. The apparatus according to claim 1, **characterized in** that the force creating means is a spring (26), preferably a coil spring.

3. The apparatus according to claim 2, **characterized in** that the drive wheel support (16) comprises a dowel (25) and a means for receiving the dowel, wherein the dowel can move within the means for recieving the dowel, and further wherein the spring (26) is in contact with the dowel, the dowel substantially enclosed by a wall of the means for receiving the dowel.

4. The apparatus according to claim 3, **characterized in** that the dowel (25) includes a collar shaped portion (27) that abuts the spring (26).

5. The apparatus according to claim 4, **characterized in** that the dowel (25) is turnably arranged and connected to a hook (30) or the like, and wherein the dowel, when the spring (26) is compressed, abuts against a stop means (32) arranged on the drive wheel support.

6. The apparatus according to any of the preceding claims, **characterized in** that the force created by the spring is substantially constant during the substantially vertical motion of the drive wheel support (16).

7. The apparatus according to any of the preceding claims, **characterized in** that the weight of the apparatus is sufficient to overcome the resulting force created by the spring.

8. The apparatus according to any of the preceding claims, **characterized in** that the nozzle is arranged at a bottom (24) of the housing (10) facing the floor surface, the bottom also including support means (14,15), preferably wheels or rolls, wherein, when the apparatus is placed on the floor surface, the support means provide a gap between the bottom of the apparatus and the floor surface when the floor surface is hard and substantially flat.

9. The apparatus according to 6, **characterized in** that the bottom (24) is substantially circular and, at least in its front part, has a peripheral smooth portion extending obliquely outwards and upwards, the bottom further including further support means (19) in its front part, the further support means positioned such that, when the apparatus is moved on the floor surface, the further support means are some distance above the floor surface when the floor surface is hard and substantially flat.

10. The apparatus according to claim 8, **characterized in** that the drive wheels (12) include shafts (13) arranged in the same vertical plane, and wherein the support means (14,15) are arranged at each side of the vetical plane, and further wherein the housing (10) is arranged to tilt about one or several of the support means (14,15) under the influence of the torque of the individually driven drive wheels when the apparatus is hindered in its movement or when the apparatus engages an obstacle.

11. The apparatus according to any of the preceding claims, **characterized in** that each drive wheel support (16) includes a micro switch (35), wherein the micro switch gives a control signal to an electric circuit of the apparatus when the corresponding drive wheel is in an extended position.

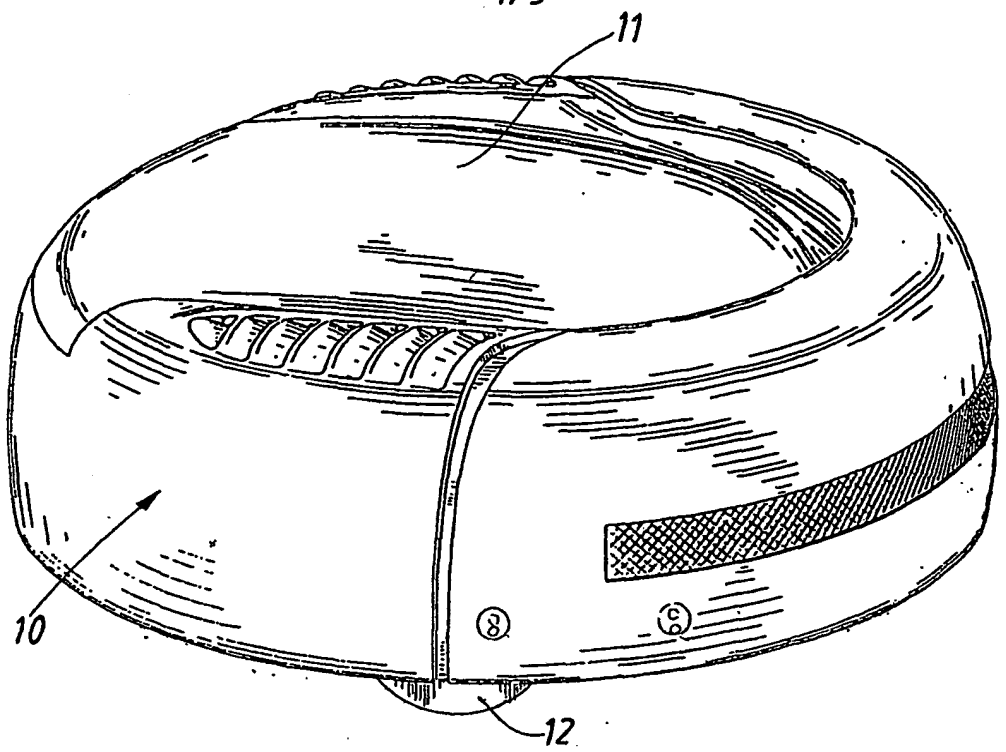

FIG. 1

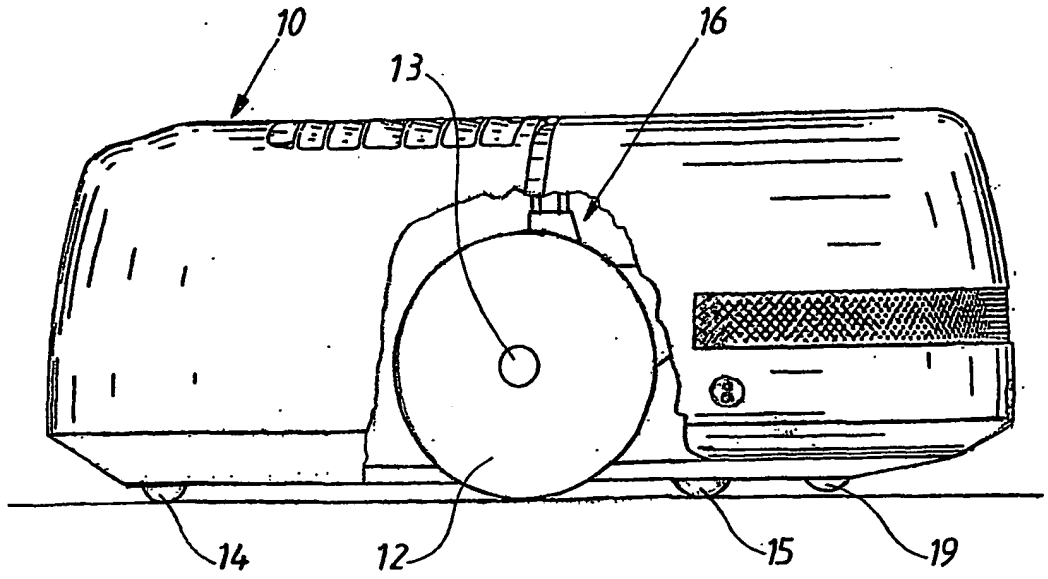

FIG. 2

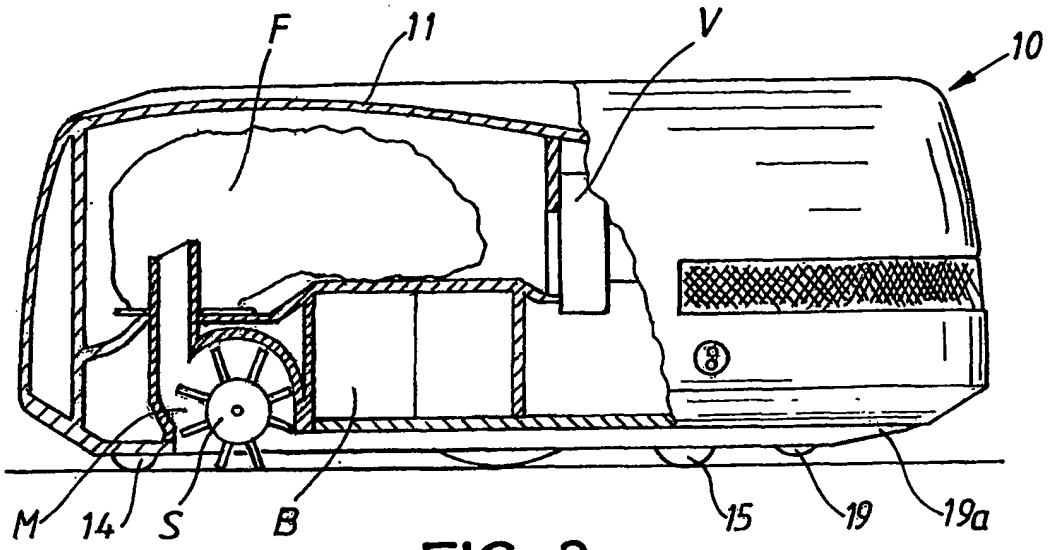
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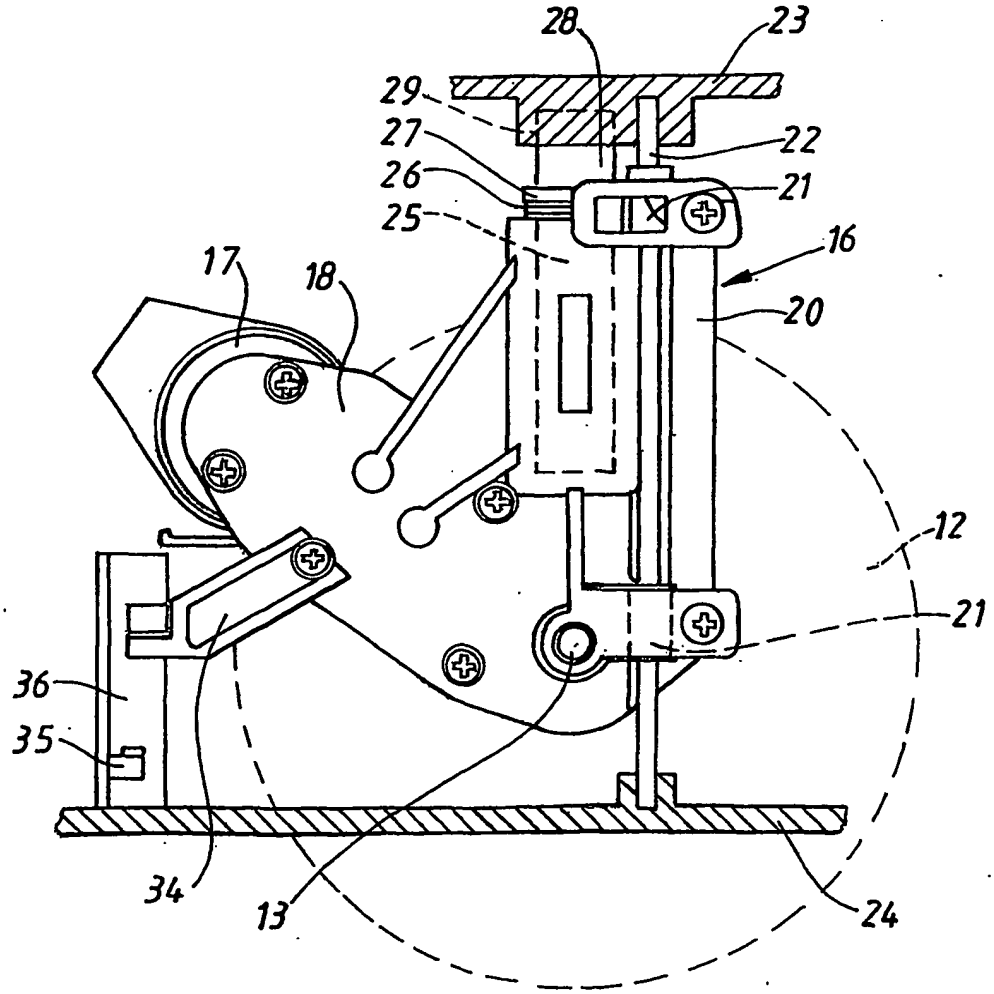
FIG. 3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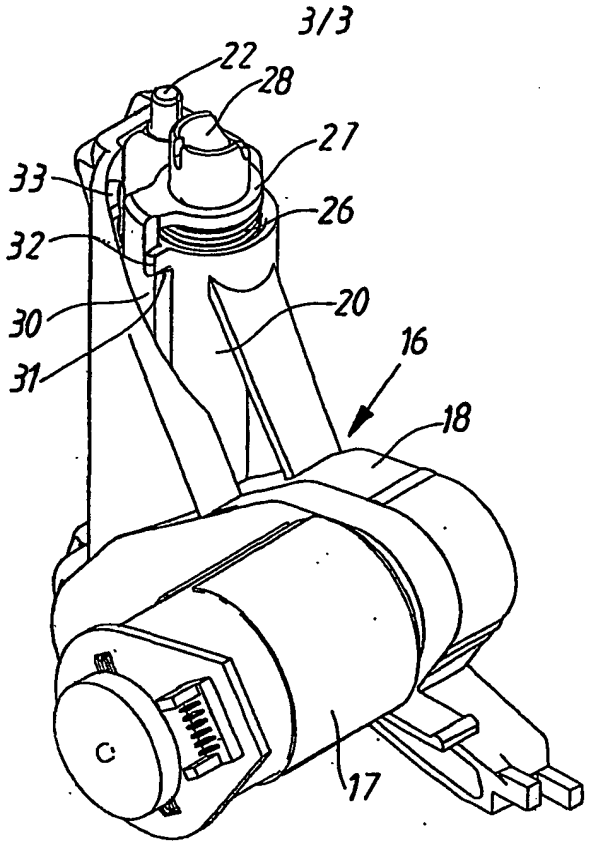
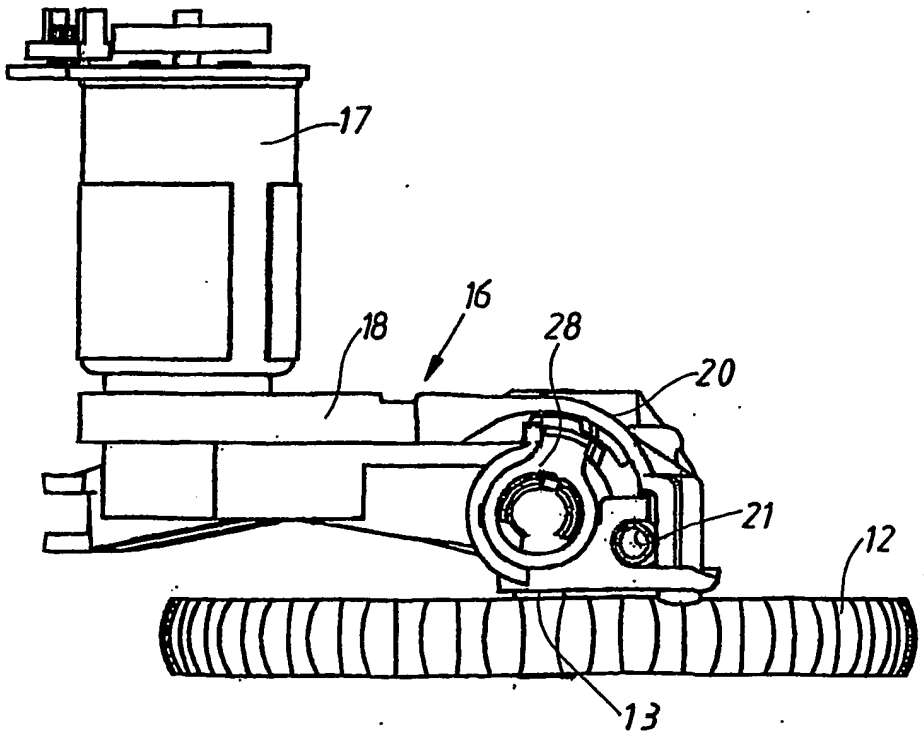


FIG. 5



INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 02/00341

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: A47L 9/00, A47L 11/40
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: A47L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5720077 A (NAKAMURA ET AL), 24 February 1998 (24.02.98), column 3, line 6 - line 13, figure 1 --	1
A	US 5815880 A (NAKANISHI), 6 October 1998 (06.10.98), column 3, line 11 - line 14, figures 1, 2 --	1

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed
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Date of the actual completion of the international search	Date of mailing of the international search report
15 April 2002	02 -05- 2002
Name and mailing address of the ISA/	Authorized officer

INTERNATIONAL SEARCH REPORT

Information on patent family members

28/01/02

International application No.
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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US 5815880 A	06/10/98	JP 9047413 A	18/02/97